A Real Options Analysis of Project Portfolios

Practitioners' Assessment

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Abstract: The purpose of this article is to assess the effectiveness and ease of implementation of the real options analysis applied by practitioners to select projects and constitute portfolios while taking into consideration managerial flexibility in project. The real options approach is based on a user-friendly bubble diagram as an attempt to overcome barriers that have so far limited the implementation of the real options analysis despite its superiority in appreciating managerial flexibility with respect to other approaches to resources allocation. Results suggest that the real options analysis seems to perform better regarding its completeness and its ability to generate balanced project portfolios but remains less appreciated according to other criteria such as the ease of interpretation.

1. Introduction

Project portfolio management is a complex and critical process that operationally translates the firm's mission and strategy into projects (Martinsuo, Korhonen, and Laine, 2014; Teller and Kock, 2013; Teller, Kock, and Gemünden, 2014). It determines firms' ability to compete by selecting their current projects and identifying learning opportunities that will shape their future knowledge and new products (Chirumalla, 2018). Ineffective portfolio management can waste scarce resources on unprofitable projects and fail to identify profitable ones, which can place firms in an extremely delicate situation with respect to its competitors (Garel, 2013) .

Portfolio management can be defined as the selection of possibly dependent projects over time to be executed at a specific speed while continuously rejecting, preparing or detecting others (Cooper, Edgett, and Kleinschmidt, 2001). Apart from the logistical and operational issues of project management, project portfolio management studies attribute two goals to portfolios: rationalizing investment decisions and optimizing the use of resources (Young, Young, Jordan, and O'Connor, 2012). They also pinpoint three maximization activities: maximizing the financial value, maximizing alignment with the company's strategy, and maximizing balance among projects (Kester, Hultink, and Kleinschmidt, 2008; Martinsuo and Lehtonen, 2007). Project portfolio value maximization refers to a situation in which an identified set of projects allows a firm to achieve the highest profitability compared to other project sets. Balance in portfolio management refers to the trade-off between risk and profitability, short- and long-term, ease of implementation and market or technology attractiveness. The link to strategy is assured when portfolio projects help the firm reach its strategic goals. However, other studies reveal that firms undertake too many projects based on their available resources, that these projects are not easy to abandon and that few projects turn out to be successful (Cooper, Edgett, and Kleinschmidt, 1998). At the same time, some studies have shown the absence of an ideal or even a dominant project management process (Cooper, Edgett, and Kleinschmidt, 1997) that successfully achieves all three portfolio management goals (i.e. value, balance and strategy). Instead, different approaches perform differently in achieving one or another specific portfolio management goal. For instance, widely studied analytical processes (Graves, Ringuest, and Medaglia, 2003; Iamratanakul, Patanakul, and Milosevic, 2008; Khalili-Damghani and Tavana, 2014) that offer powerful optimization techniques are usually not preferred by practitioners who describe them as "black boxes" (Cooper et al., 1997; Jonny Klakegg, Torp, and Austeng, 2010). Other qualitative approaches, such as bubble diagrams, are user-friendly and visual, but usually lack a cutting-edge rule that allows managers to abandon unprofitable projects, a decision that is difficult and unpopular when these projects have been proposed or adopted by executives or when such a decision has a negative impact on the project team members.

Some of the most popular approaches remain traditional financial analyses based on discounted cash flows (DCF) such as net present value (NPV) and internal rate of return (IRR). However, strategically, these analyses have a serious drawback: they do not allow for the evaluation of highly valuable sources of flexibility. Specifically, traditional financial analyses do not account for portfolio managers' ability to react to new information, relying instead on the assumption that the project portfolio will be executed as it was initially identified and planned.

Traditional financial analyses therefore do not account for strategic decisions that could be made as risks or opportunities emerge during project implementation. Instead, real options analysis (ROA) (Dixit, 1994) allows valuable sources of flexibility to be taken into account when managing project portfolios (Montajabiha, Arshadi Khamseh, and Afshar-Nadjafi, 2017; Olsson, 2006).

1.1. Managerial Flexibility at the Project Level

At the project level, ROA allows for more accurate project valuation by taking into consideration sources of flexibility inherent to the project. For instance, it is usually possible to delay the project's start or to accelerate its implementation. Also, project managers usually split project implementation into multiple stages and consider "go" and "no go" decisions after each stage, which may account for the popularity of the stage-gate approach (Cooper, 2008). Obviously, this flexibility adds greater value to the project at hand. Referred to as managerial flexibility, it is imbedded in project management, offering some options "on the project," to be distinguished from other options "in the project," which are related to the project output design (Binder, Paredis, and Garcia, 2017; Olsson, 2006; Tokunaga and Fujimura, 2016; Wang and De Neufville, 2005). Managerial flexibility is similar to financial options, in that the focus is on financial metric parameters such as the NPV.

Some project management studies have pointed out that uncertainty may provide project managers with unique opportunities to enhance project value and acquire significant competitive advantages for the project company (Böhle, Heidling, and Schoper, 2015; Lechler, Edington, and Gao, 2012). However, these studies rely on the assumption that unexpected opportunities can be seized in a timely fashion and that unexpected risks can be effectively turned into opportunities without previous actions carried out during the planning stage. While it is true that unexpected events cannot be specifically accounted for during the planning stage, we argue that it is possible for the project company to incorporate some sources of flexibility into the project scope, budget or schedule during the project definition stage in order to manage opportunities and risks as they unfold later. Furthermore, we show that incorporating some sources of flexibility at the project level allows unique opportunities to be seized and identified at the portfolio level, enhancing the project company's competitive advantages.

1.2. Managerial Flexibility at the Project Portfolio Level

A project cannot be evaluated in isolation from other projects under evaluation or in execution, since interdependencies between projects have to be considered for adequate risk management (Ackermann, Eden, Williams, and Howick, 2007; Adner, 2006; Kwan and Leung, 2011; Teller, 2013; Teller et al., 2014). Because of these interdependencies, some sources of managerial flexibility at the project level may become more valuable at the portfolio. To illustrate, a common situation is the value of a "learning project" (Project I) that is meant to provide adequate conditions for an initial move into a new sector (Project II). Project I cannot usually be financially viable unless it is followed by Project II, a bold, albeit uncertain, commercial extension. A company that considers Project I in isolation will probably not implement it, but a project company that assumes Project I will be successfully followed by Project II may wrongly commit valuable resources to an unprofitable project. In reality, Project II's value depends on the information that Project I provides. At the end of Project I, the project company will have the opportunity but not the obligation to launch Project II if it is deemed profitable at that time. This managerial flexibility must be considered and planned for during the evaluation phase. Without such sources of flexibility, companies become "unable to accumulate knowledge and experience necessary for coping with uncertainty" (Perminova, Gustafsson, and Wikström, 2008). Failing to allow for the flexibility to commit to Project II later, once new information becomes available, may result in forgoing Project I, which is probably a valuable opportunity. Nevertheless, companies need to compare the uncertain profit from Project II with the early and almost known costs that will be incurred once the project company is engaged in Project I. This can be achieved by applying ROA.

1.3. The Research Question

Despite the advantages of ROA, its application in project and portfolio management has focused mainly on theoretical aspects rather than on applicability in business environments and the way it is perceived by practitioners and managers (Copeland and Tufano, 2004; Oliver, 2008; Perlitz, Peske, and Schrank, 1999), with the exception of a few studies, such as that of Ford and Lander (2011). To fill this gap, particularly in project management, we assessed the effectiveness and ease of implementation of ROA for project portfolio management. More specifically, we assessed how ROA may help project and portfolio managers to better exploit what is called the potential of uncertainty (Böhle et al., 2015) to increase project and portfolio values and improve strategic management decisions. The research question is therefore the following: How do project and portfolio managers, perceive ROA when evaluating and selecting projects with managerial flexibility in a context of uncertainty?

In order to balance between sophistication and user-friendliness in management systems (Jonny Klakegg et al., 2010), we presented a simplified real options approach (Luehrman, 1998a; Luehrman, 1998b) to participants who work in a manufacturing company. These participants were then interviewed to identify and analyze their assessment of ROA compared to more traditional financial analyses. The research focused on the quality of information (Bovee, 2004) obtained from ROA as perceived by the various groups of participants.

ROA is introduced in Section 2. A particular approach to portfolio management proposed by Luehrman (1998b) is presented in Section 3, which we refer to as "The Project Garden" (PG). Since it is based on a bubble diagram, PG seems suited to use by non-financial experts in making portfolio management decisions. In Section 4, we provide examples to illustrate how ROA allows flexibility to be taken into consideration when managing projects of a given portfolio and therefore enhances its strategic value. In Section 5, research methodology and data collection are presented. We explain how PG had been presented to different groups of participants in a manufacturing company and how they applied it to select and prioritize a portfolio of new development projects (NDP). Section 6 describes how participants perceive the application of ROA to select and prioritize a portfolio NDP with respect to more traditional financial analyses. In Section 7, we discuss the research results and limitations and propose further avenues for future research. We offer conclusions in Section 7 on the applicability of PG in practice and its added value compared to traditional financial analyses.

2. The Real Options Analysis

ROA has its roots in financial options with Black and Scholes (1973) and Merton (1973). A financial call option is a contract that grants its owner the right but not the obligation to buy (or to sell in the case of a put option) a specific quantity of commodities or financial stocks at a predetermined price at some point in the future (European option) or within a specific time interval in the future (American option). Financial option analysis allows valuing such options, determines when an option should be exercised, and, in particular, shows that the value of the financial option increases when the variance of the underlying financial asset, that is the uncertainty level, increases. Whereas financial options are related to financial assets, options related to project management, product design and development, natural resources exploitation, and so on are called real options, because decisions concern physical assets. However, some differences remain between financial and real options, and these have been highlighted in the literature (Blum, 2012; Garvin and Ford, 2012; Haahtela, 2012; Lautier, 2001). Most important is the impact of strategic competition on the maturity period, as the investment opportunity will not usually remain hidden or protected from competitors. Strategically, this means that the owner may be better off exercising the option to pre-empt potential competitors and opt for accelerating the project implementation.

In the 1990s, ROA emerged as a tool for making decisions in the face of uncertainty in situations where the decision-making process allows for some flexibility and implies irreversible consequences. Uncertainty, irreversibility and flexibility are the three conditions under which ROA surpasses traditional financial analyses for project evaluation and risk management. The positive relation between the financial option value and the level of uncertainty applies also to real options. It is a crucial aspect of real options and can be summarized as follows: uncertainty adds value to a project, since when available, flexibility protects a project from the impact of a future negative event while allowing it to take advantage of a future positive event. This mindset is a part of ROA and constitutes a different way for managers to look at uncertainty, which is usually associated with risk but not with opportunity (Böhle et al., 2015; Lechler et al., 2012; Olsson, 2006; Perminova et al., 2008). Indeed, uncertainty may leave project managers with unique opportunities to create value if a project has enough sources of flexibility. Real options can be arranged into several categories, including postponement options, staging options, abandonment options and growth options (Trigeorgis, 1996). In particular, growth options are attractive project opportunities that are created because of other previously implemented projects.

Based on a survey of 34 companies, Triantis and Borison (2001) showed that ROA has been applied in a variety of industries including energy, transportation and high technology. Focusing on project management, Huchzermeier and Loch (2001) proposed a real options model to evaluate flexibility in an R&D project in situations of market and operational uncertainty. They assumed that the value of an R&D project stems from its market payoff (price and sales), which is subject to uncontrolled factors such as competitor moves, demographic changes and substitute products. Uncertainty is related to the performance, cost and duration of a project, as well as market requirements. To manage these sources of uncertainty proactively, project managers can abandon the project, continue it without further modifications or improve its design at regular intervals. Based on an experiment depending on the development of an uncertain project, Ford and Lander (2011) aimed to capture the differences and similarities between theoretical ROA and how managers intuitively face uncertainty. They showed that managers conceptually understand real options and value managerial flexibility as predicted by the theory.

To acquire a real option, project managers usually incur a certain cost. Once the real option is acquired, its owner may or may not choose to exercise it at a specific point in the future or within a predetermined period. Exercising a real option usually comes at a cost as well. To illustrate, consider the following example at the project level. The manager of a new gold mine project is about to rent equipment for the mine processing plant at a time when the price of gold is particularly uncertain (high price volatility). If the price of gold increases, it will be profitable to extract and process high quantities of ore, including ore with low gold content. If the price of gold decreases, the manager is better off extracting and processing limited quantities with high gold content to limit processing costs and keep extraction profitable. Under these circumstances, the manager may opt for low capacity and upgrade if the price of gold increases. However, this alternative remains risky because the equipment may not be available or may be highly expensive if needed later. Therefore, the manager is better off renting low-capacity equipment and acquiring an option (a contract) that gives her the right to rent additional equipment at a predetermined cost (strike price) within a given period. In this example, uncertainty related to the price of gold is external to the project, in the sense that it is beyond the project stakeholders' influence. If the uncertainty were internal, the project manager would take action to reduce it. For instance, if the uncertainty were related to ore quality, the project manager would have good reason to undertake further exploration activities. From now on, uncertainty is assumed to be external to exclude project stakeholders' activities that may be implemented to reduce risk occurrence or impact.

When considering the irreversibility of project investment and the uncertainty related to future events that could impact project profitability, ROA shows that NPV should be higher than a certain positive value for the project to be launched. This positive value reflects the loss of the possibility to make decisions down the road. ROA is therefore based on the NPV concept and is not a complete departure from it. More precisely, ROA and NPV are expected to lead to the same conclusions when flexibility is not affordable. However, ROA entails a different way of thinking about uncertainty that is likely to alter the way projects are managed and affect how related risks are considered and addressed. In short, in line with ROA, a project is not launched as long as its NPV does not exceed the investment cost plus the cost of not waiting for any additional information that may be obtained if the investment is further delayed. The latter cost reflects the value of waiting for more information and increases with the uncertainty level as forthcoming information becomes more valuable. The value of waiting for more information explains why decision-makers prefer postponing investments when there is a high level of uncertainty.

With respect to project portfolio management, ROA shows that decision-makers are not limited to "go" or "no go" decisions with respect to a given project but can opt to postpone its launch while cultivating and preparing other projects. They may delay final commitment to a given project by using the "late locking" or "continuous locking" processes outlined by Olsson (2006) while implementing other projects. Of course, postponing or splitting projects is not necessarily a winning strategy, because the cost may exceed the expected gain from delaying commitments. In this sense, ROA offers a quantitative tool to identify the moment when it is necessary to make such timely decisions. Generally, that moment is not determined explicitly as a specific moment in time, but implicitly as a function of certain observable variables such as the current project's value or the demand for a service or a product, such as the price of gold in our example.

3. The Project Garden

Assume that the project company is assessing a project whose present value is S and investment cost is X. The uncertainty related to the project's future cash flows implies an uncertain rate of return with a standard deviation or volatility σ. Assume that the project can be deferred for a given period of time t, referred to as a waiting or a maturity period. In this situation, the project is similar to a European option (a call), as the project company has the right but not the obligation to incur the investment cost X at the end of the maturity period t, if the project is deemed profitable. Mapping such an investment opportunity onto a European option (call) is straightforward. The project's present value S corresponds to the stock price. The project investment cost X corresponds to the option strike price. The project maturity period t corresponds to the option expiry period. The standard deviation σ of the project rate of return corresponds to the standard deviation of the stock rate of return. Under these conditions, the current value W of the project is given by the following formula of Black and Scholes (1973):

$$w = SN(d_1) - Xe^{-rt}N((d_2))$$

$$d_1 = \frac{\ln\left(\frac{S}{X}\right)+\left(r+\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{\ln\left(\frac{S}{X}\right)+\left(r-\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}} = d_1 - \sigma\sqrt{t}$$

In the B&S formula, S is the project's present value, σ is the standard deviation of the present value, X is the investment cost, t is the maturity period, r is the risk-free rate of return, and N(x) is the cumulative normal function.

Note that when it not possible to delay the project (t = 0), then *W* reduces to the project NPV. Indeed, if S > = X, $d_1 = d_2 = +\mu$, $N(d_1) = N(d_2) = 1$, and W = S-X. If S<X, then $d_1 = d_2 = -\mu$, $N(d_1) = N(d_2) = 0$, and W = 0. Similarly, if there is no uncertainty ($\sigma = 0$), then *W* reduces to the project NPV. For more insights into mapping an investment opportunity onto a call option, see for instance Luehrman (1998a); Tahon, Verbrugge, Willis, Botham, Colle, Pickavet, and Demeester (2014); Yeo and Qiu (2003).

The B&S formula, which allows for the calculation of the project value while taking into account flexibility value, seems unappealing for practitioners given that its input variables that are not so intuitive. Interestingly, Luehrman (1998a) pointed out that the ratio of the real option value W over the project's present value S, hereinafter referred to as the option relative value, can be expressed as a function of only two variables that seem more intuitive to practitioners:

$$\frac{w}{s} = N(d_1) - \frac{N(d_2)}{V}, \text{ where } d_1 = \frac{\ln(V)}{U} + \frac{U}{2},$$

$$d_2 = \frac{\ln(V)}{U} - \frac{U}{2} = d_1 - U, \; V = \frac{S}{X e^{-rt}}$$

is the value-to-cost ratio, and $U = \sigma\sqrt{t}$

is the cumulative uncertainty.

The value-to-cost ratio V is equal to the project present value over the cost present value. It reflects the gain that will be earned if the investment is postponed, as the present value of the cost diminishes when the investment is delayed. The cumulative uncertainty U refers to the level of uncertainty that is dependent on the volatility of the project value σ and the maturity period t. Therefore, cumulative uncertainty implies that a project is riskier if its value is more volatile and its maturity period is longer. The last B&S formula is more appealing for practitioners because it gives the option relative value as a function of only two intuitive variables, and can be approximated from a pre-established financial table (**Table 1** in the Appendices). For instance, a project with a present value S = $100, an investment cost X = $80, a return volatility σ = 30%, and a maturity period of two years (t = 2), has a value-to-cost ratio of V = 1.4 and a cumulative uncertainty of U = 0.40 (assuming a risk-free rate of return equal to 5%). **Table 1** shows that its relative option value is W/S = 32.3%. Therefore, the option value equals $32.3. The difference between the NPV of the project as an option (NPVoption=32.3$) and the traditional NPV of the project

$$NPV = S - e^{-rt}X = \$27.44$$

is the value of the flexibility, equal to 18% of the traditional NPV. If the volatility σ increases from 30% to 40%, then the flexibility value increases from 18% to 30% of the traditional NPV. Furthermore, if the maturity period increases from two to five years, the flexibility value reaches 35% of the traditional NPV.

With respect to a project portfolio, Luehrman (1998b) proposed a bubble diagram called "The Tomato Garden," which we refer to as "The Project Garden" (PG). In this diagram, each project is represented by the pair (V, U) as illustrated in **Figure 1**, where the surface of the dotted circle represents the investment cost X and the continued circle represents the project present value S.

As shown in **Figure 1**, a project can be located in six different zones according to the value-to-cost V and uncertainty U numerical values. First, consider the case in which a project cannot be postponed or can no longer be postponed, i.e., t = 0 and therefore U = 0. In this situation, the option value is Max (S-X, 0), where S-X is simply the project NPV. The project is profitable if S-X > 0 or V > 1, and the project is not profitable if S-X < 0 or V < 1. In the first case (V > 1, U = 0), the project must be launched (Zone 1: Invest immediately), and in the second case (V < 1, U = 0), the project has to be rejected (Zone 6: Never invest). Decisions in Zones 1 and 6 concur with the NPV rule as it is no longer possible to postpone the project at hand.

Second, consider the case where the commitment to the project can be delayed for some period t (a maturity period). In this situation, the project must be evaluated as an option that will be exercised at the maturity date only if it is worthwhile. Note that even when the current value-to-cost V is higher than 1 (i.e. the NVP is positive), it is still not profitable to launch the project because the project value S is not sufficiently higher than the investment cost X and may decrease below the investment cost X shortly after the project launch. More specifically, the current value-to-cost V may increase or decrease drastically if V is too volatile (σ is high) or if the maturity period is too lengthy (t is high). Depending on the current value of V, cumulative uncertainty U determines the probability of the project reaching the project launch date while remaining profitable. Consequently, in **Figure 1**, four other zones appear in the area of the graph in which the cumulative uncertainty is strictly positive (U > 0). Qualitatively, these four zones may come into play depending on whether the current cost-to-value V is higher or lower than 1 and whether the cumulative uncertainty is high or low. With high value-to-cost and low cumulative uncertainty, projects in Zone 2 will remain profitable when it is time to commit to the project. Projects in Zone 3 have value-to-cost values just above 1, but they are more volatile; it would be still possible for them to reach the maturity date while remaining profitable, but this is less probable than for projects in Zone 2. Projects in Zone 5 appear not to be profitable and their cumulative volatility is low; they will most likely reach the maturity date without being profitable. Projects in Zone 4 are not far from being profitable and their cumulative volatility is still high; they may reach the maturity date while being profitable. In this model, Zones 3 and 4 are separated by the axis (V = 1), but it is not yet clear how to separate Zones 2 and 3, or Zones 4 and 5.

Note that without accounting for external competition or the pressure to launch a project earlier, it would be worth committing to a project only after the maturity period (t) if it is deemed profitable (S > X). However, sudden moves by competitors, events in the market and a myriad of other unexpected changes in the project environment may lead project managers to consider an earlier project launch than anticipated when a project is already profitable, i.e. S-X > 0. To this end, Luehrman (1998b) proposed separating Zones 2 and 3 by the curve where S-X = 0 separates projects that can be launched immediately from those that must be delayed. Each project is represented by two concentric spheres at point (V, U) whose diameters are (S) and (X) respectively, to distinguish those with a positive NPV (S-X > 0) from those with a negative NPV. Consequently, projects in Zone 2 have a positive NPV and may be launched immediately based on strategic considerations (Maybe Invest Now).

By contrast, projects in Zone 3 are not immediately profitable, and it is therefore worth waiting before considering launching them (Probably Invest Later). Zone 4 (Maybe Invest Later) and Zone 5 (Probably Never Invest) are separated by the curve, which provides symmetry with respect to the vertical axis (V = 1) of the curve S-X = 0 separating Zones 2 and 3. For more information, readers may refer to Luehrman (1998b).

4. Enhancing Project Portfolio Strategic Value

Used alone, traditional financial tools do not allow for selection of projects that are aligned with the firm's strategy. Instead, portfolio managers have to pre-select projects that fit into the firm's strategy, through, for instance, strategic buckets (Cooper et al., 1998). The PG can then be applied to each bucket, considered as a project portfolio, in order to select, prioritize and schedule projects within each bucket that maximize value while relying on managerial flexibility to cope with uncertainty, taking advantage of positive events offering opportunities and avoiding negative events presenting risks. Portfolio managers who rely on managerial flexibility to create unique opportunities or growth options (Kulatilaka and Perotti, 1998) for the firm can then use uncertainty to their advantage and enhance the firm's competitive advantage. Indeed, a clearly profitable opportunity should attract many competitors. However, an opportunity that seems less attractive because it is fraught with uncertainty will attract fewer competitors, but may lead to other options that, when considered together, would create unique competitive capacities for their holder. Relying on managerial flexibility in portfolio management allows project managers to enhance the firm's competitive strategy. In this context, ROA is used to help make a decision about seizing a seemingly unattractive opportunity and avoiding unnecessary resource consumption.

The manager of a given project portfolio must proactively recognize the different sources of managerial flexibility embedded in each project of the portfolio. For each project, but particularly for unattractive projects, the manager has to assess the five variables in the B&S formula, namely project present value (S), investment cost (X), financial return volatility (σ), maturity period (t) and risk-free rate of return (r). With the exception of risk-free rate of return (r), the manager can generally proactively influence the other four variables, as well as project interdependency, to enhance the overall portfolio value. More specifically, as portfolio management includes ways to cope with the unexpected (Geraldi, Lee-Kelley, and Kutsch, 2010), it is crucial to know how to stage, accelerate or delay the implementation of certain projects, the cost of such strategies, and whether they are worthwhile. Decision-makers need to view the various projects holistically by visualizing the impact of changes in the PG variables detected through continuous updates of the portfolio projects and the firm environment. Consequently, the PG not only simplifies ROA while retaining its advantages for selecting highly profitable projects and those with valuable flexibility, but it also leaves room for timely reactions. The PG can therefore be used as a tool to quickly illustrate changes in the firm's environment, understand their impact on the project portfolio and provide an opportunity to re-evaluate and update the firm's strategy. Indeed, the PG offers a valuable means of graphically representing the impact of sudden changes in the firm's dynamic environments by properly translating these changes into changes in the B&S formula's input variables for all the projects in the portfolio, especially in terms of maturity periods, return volatilities and any dependencies between them.

Recall that the project maturity period is the period before commitment to the project. Commitment is practically irreversible in the sense that abandoning the project would be impossible or simply too harmful to the project company. The maturity period can be determined to some extent as a function of allocated resources and the characteristics of concurrent projects. As previously mentioned, the portfolio manager may decide to intentionally reduce the project's maturity period in order to pre-empt potential competitors.

The volatility of the project's financial return is harder to determine, as managers are less accustomed to doing so. Generally, project volatility may vary between 30% to 60% on average (Luehrman, 1998a). To obtain a more informed estimate of the volatility of a given project, project managers can use historical data on financial rate of return for similar projects. It is also possible to derive a project's financial return volatility by simulating its future revenues using, for instance, the Monte Carlo simulation technique applied to the project's annual cash flows (Copeland and Antikarov, 2001; Godinho, 2006).

To illustrate how the PG can be used to take into consideration and graphically represent the managerial flexibility inherent in a project and how this flexibility enhances the overall project portfolio value, reconsider the two-project portfolio in Section 1.2. Recall that the first project (Project I) is a "learning project" that can be followed three years later by a second project (Project II) if that project is deemed profitable (Growth option). **Table 2** summarizes data and calculations of Project II's value as a growth option where the risk-free rate is 5%.

The NPVs of Project I and Project II are respectively $10 and -$60, and both projects have a total negative NPV (-$50) as shown in **Figure 1**. Project I and Project II (without flexibility) have a total value-to-cost lower than 1. Using traditional NPV techniques, the portfolio manager would ignore both projects or invest in Project I and systematically ignore Project II (see Figure 1). However, although Project I may not be highly profitable, it provides an opportunity, since Project II may become profitable in three years. As shown in **Figure 1**, Project II is in Zone 5 (Probably Never Invest), not far from Zone 4 (Maybe Invest Later). Considering Project II as a European option, its value-to-cost ratio V = 0.8 and cumulative uncertainty U = 0.5 can be computed, and **Table 1** can be used to show that its relative option value is 11.5%. Thus, the option value or simply Project II's value is W = $23. The overall portfolio therefore has a value of $33 instead of -$50, as shown in **Figure 1** (Project I and Project II with flexibility). Thus, ROA indicates that the portfolio manager needs to implement Project I and keep monitoring Project II.

As mentioned earlier, the PG allows the portfolio manager to illustrate how proactive management can influence the project portfolio perspective. For instance, **Figure 1** shows how the project portfolio would improve if the portfolio manager could act to increase the value of Project II, decreasing its cost (white arrow) or increasing its maturity period (black arrow).

5. Research Methodology and Data Collection

ROA has been criticized mainly because it relies heavily on complex mathematical analysis, which has hampered its popularity in practice (Baker, Dutta, and Saadi, 2011; Block, 2007; Ford and Lander, 2011). The PG may help address these concerns, as it is based on a user-friendly bubble diagram and may provide an easier and ultimately more popular approach for applying ROA in portfolio management.

In this section, we seek to verify this hypothesis through a survey and assess the quality of perceived information (Bovee, 2004) when applying the PG to select and prioritize a portfolio of new development projects (NDP). A survey was conducted to collect and analyze participants' opinions with respect to NPV, ROA and Statement of Revenues and Expenses (SRE) analysis, which is currently used by the participants' company to establish NDP portfolio. It consists of estimating the undiscounted project cash flows in its early years. In other words, projects with the shortest non-discounted payback periods are preferred. Participants were divided into four groups according to their roles in the firm: finance personnel (one group of seven participants), managers (one group of eight participants) and project managers (two groups of seven participants each). To ensure that participants understood the two methods (NPV and ROA), neither of which were currently used by the participants, the methods were presented to all participants as neutrally as possible before they were provided with the questionnaire. The presentation was performed to the four groups separately. The presentation and the questionnaire were tested with two participants deemed representative of the target population and then adjusted. In total, 29 invitations were sent. Only 24 participants attended one of the four presentations. Six out of seven finance personnel attended; five out of eight managers attended; and 13 out of 14 project managers attended. After each presentation, a questionnaire was sent to the attendees through internal mail. They were asked to send their answers back in a pre-addressed envelope. In total, 23 questionnaires were answered and sent back, representing 79% of the targeted population.

Many information quality (IQ) studies assume certain relationships between information attributes and overall information quality. Bovee (2004) validated empirically a general model of IQ in the health sector using partial least squares. Bovee (2004) outlined four main IQ attributes: Accessibility, Interpretability, Relevance and Integrity. Integrity encompasses four criteria: Accuracy, Completeness, Consistency and Existence, which refers to information non-fictitiousness and non-redundancy. Relevance includes Currency and other criteria specific to the company's sector of activity. Currency includes Age and Volatility of information (**Figure 2** in the Appendices).

The survey questions were divided into three sections. The questions in the first two sections of the survey were inspired by Bovee (2004) and Sakka (2007) with respect to IQ attributes, and from the previously mentioned literature related to real options criticism and project portfolio management.

The questions required a psychometric answer on a Likert scale of 1 (completely unimportant/disagree) to 5 (completely important/agree). The first section included 15 questions to identify the most important IQ criteria for participants. The second section included 41 questions to assess participants' opinions about each of the three analyses (SRE, NPV and ROA) with respect to the following IQ attributes: Accessibility, Interpretability, Relevance, Accuracy, Completeness, Consistency and Existence from Bovee (2004), Level of Detail from Sakka (2007), and Project Portfolio Quality. In this section, questions related to the same attribute with a Cronbach's alpha reliability coefficient higher than 0.7 were grouped together. The third section of the survey included two demographic questions (group and experience) in addition to an open question in which participants were asked to recommend one analysis and to justify their choice. The survey included a total of 141 questions. See **Table 3** for a summary of the survey results and **Table 4** for a summary of the survey questions in the appendices.

6. Results

The first section of the survey aimed to identify the most important IQ criteria for participants to manage portfolios of NDP. It shows that "Understandability of financial information on new products" (Understandability) and "Having a project portfolio that reflects the strategy of the organization" (Project Portfolio Fit) obtained the highest score (4.74 (0.45)), followed by "Quality of financial information about new product" (Financial Information Quality) (4.70 (0.47)). Below, we will describe the main differences between IQ attributes when one of the three analyses is used. The survey is summarized in **Table 3.**

With respect to Accessibility, ROA received a lower score than the other two analyses. Grouped questions related to Accessibility (alpha = 0.697) included, for instance, whether the analysis "needs information that is easy to obtain" and whether the analysis is "easy to apply in practice." The average score was 3.79 (0.62) for SRE, 3.58 (0.68) for NPV and 3.23 (0.77) for ROA. ROA also scored lower than the two other analyses on Interpretability, although the three related questions have not been grouped (alpha = 0.474).

Specifically, the average score of whether the analysis seems "easy to understand" was 4.43 (0.68) for SRE, 3.81 (0.87) for NPV and 3.00 (0.873) for ROA. In terms of whether the analysis seems "easy to interpret," the score was 4.33 (0.796) for SRE, 3.91 (1.019) for NPV and 3.00 (1.024) for ROA. However, the results of the question on whether the analysis "does make sense," were 4.25 (0.716) for SRE, 4.33 (0.577) for NPV and 4.29 (0.784) for ROA.

With respect to Relevance, NPV was perceived as slightly more relevant than the other analyses, albeit not significantly. Grouped questions related to Relevance (alpha = 0.736) included whether the analysis seems "relevant and meets the firm's needs." The average score was 4.20 (0.61) for SRE, 4.27 (0.64) for NPV and 4.07 (0.74) for ROA.

Questions related to Accuracy have not been grouped (alpha = 0.454). In particular, the average score for the question of whether the analysis "seems error-free" was 3.29 (1.31) for SRE, 3.41 (1.14) for NPV and 2.86 (1.17) for ROA. Results of the question on whether the analysis seems "accurate" were 3.86 (0.66) for SRE, 3.82 (0.50) for NPV and 3.41 (0.85) for ROA.

With respect to Completeness, grouped questions (alpha = 0.753) included whether the analysis seems complete enough "to make a decision", "to consider risks properly in the long run", "to establish firm strategy", and "to reflect managerial flexibility". The average score was 2.98 (0.44) for SRE, 3.30 (0.51) for NPV and 4.05 (0.52) for ROA.

Only one question was related to Existence, on whether the information was reported "without duplicates." The average score for this question equaled 3.31 (0.60) for SRE, 3.50 (0.73) for NPV and 3.69 (0.79) for ROA. Thus, ROA seems to provide information with less duplication when compared to the other two analyses.

With respect to Consistency (of NPV and ROA when compared to SRE) and Level of Detail, there was a low or no significant difference between the different analyses.

Grouped questions related to Project Portfolio Quality (alpha = 0.876) included whether the analysis seems to "help prioritize projects", "build a balanced portfolio in the long run versus in the short run", and seems "well diversified with respect to risk management." The average score was 2.81 (0.76) for SRE, 2.98 (0.66) for NPV and 4.40 (0.52) for ROA. ROA seemed to perform better on the Quality of Project Portfolios when compared with the other analyses.

When we examined differences in opinions based on positions at the company, management and finance personnel perceived Financial Information Quality (0.025**) and Accuracy (0.048**) to be less important than project managers did. Also, the Project Portfolio Fit seemed more important for project managers and managers than for finance personnel (0.012***).

With respect to the differences between participants' answers from group to group, we found differences relating to Understandability (0.049**), Consistency (0.049**), Project Portfolio Quality (0.044**), and finally, Project Portfolio Fit (0.044**) for ROA, all of which were scored lower by managers.

We also analyzed results based on staff experience. Experience was classified using four levels: less than two years (4 people), from two to five years (4 people), from six to ten years (7 people) and over ten years (8 people). We noted that for SRE, Completeness was perceived as less present by more experienced participants (0.003***), but there was no difference between NPV and ROA for this criterion. In all three analyses, Accessibility was perceived as significantly different based on experience (SRE = 0.024**; NPV = 0.008***; ROA = 0.010**). The more experience participants had, the lower they scored Accessibility for all analyses (respectively 0.001****; 0.011*** and 0.030***).

Finally, participants were asked to recommend a preferred analysis. Out of 23 people, 12 chose ROA (8 project managers, 3 finance personnel and 1 manager), three chose NPV (2 finance personnel and 1 manager), three chose SRE (2 managers and 1 project manager), two chose a mixed analysis (1 finance personnel and 1 project manager), and two did not give an answer.

7. Results Discussions and Limitations

The first section of the survey confirmed that participants are concerned with the understandability of the analysis to be used for portfolio management (Cooper et al., 1997b) and its ability to provide a portfolio that fits the firm's strategy (Cooper, Edgett, and Kleinschmidt, 1997a; Kaiser, El Arbi, and Ahlemann, 2015).

The second section of the survey showed that, on the one hand, ROA seems better for prioritizing projects and building portfolios that are balanced in the long term over the short term and that are well diversified with respect to risk management. ROA was also considered more complete than the other analyses to make decisions, and better reflects managerial flexibility.

On the other hand, participants perceived ROA as more difficult to understand and interpret, less accessible, and less error-free than the two other analyses. Nevertheless, participants considered that ROA makes sense and found it more relevant than the other two analyses, although only slightly. These results confirmed Ford and Lander (2011) conclusions with respect to the consistency between managers' perceptions of flexibility and the real options theory. The survey also confirmed that managers are less enthusiastic than other participants about deploying ROA for project portfolio management, as noted in Block (2007).

During the presentations, participants indicated some ambivalence about the concept of ROA and specifically PG. On the one hand, they were willing to consider the full potential of ROA. They also appreciated the PG's graphical representation of the projects as a function of the two dimensions of return and risk. Finally, they appreciated the possibility of using the PG to visualize the impact of changes in the project variables to learn how they could improve the project portfolio and refine their strategy.

On the other hand, we noted some reserves among participants about ROA. Some suspected that project valuation was over-estimated by ROA, with which they were unfamiliar. Overall, the opinions about ROA compared to the other two analyses revealed a relatively large discrepancy, as can be seen in the survey. ROA seemed to perform better on Completeness and Project Portfolio Quality, but remains less appreciated on most other criteria. Finally, about half of the participants recommended using ROA.

Although appreciated for their simplicity, some of the features of the PG-ROA approach proposed by Luehrman (1998b) should be improved. For instance, the curve separating Zones 4 and 5 when the project NPV is negative should be improved (**see figure 1**). A possible avenue is to link these zones to the risk deemed acceptable by the portfolio manager. As limited Accessibility of ROA may be partially explained by the difficulty of estimating the uncertainty level, another avenue for improving ROA's accessibility is to look for more practical approaches to estimate NPV volatility.

8. Conclusion

Luehrman (1998b) proposed a simplified approach allowing non-financial experts to apply ROA in project portfolio management. Projects engender not only "go" or "no go" decisions, but four additional decisions, based on project value and risk, as well as managerial flexibility. These decisions are represented in a bubble diagram that is referred to here as "The Project Garden" (PG), which seems appealing to portfolio managers. To assess the effectiveness and ease of implementing the PG for portfolio management, we conducted a survey of the opinions of the practitioners to whom the PG was presented. The survey questionnaire focused on the IQ attributes as perceived by the various groups of participants. Overall, almost half the participants recommended ROA. Their opinions on ROA compared to NPV indicated a relatively large discrepancy. ROA seems to perform significantly better in terms of completeness and the ability to generate balanced project portfolios, but does not perform as well when it comes to other criteria. The reluctance of some participants to embrace the PG is predictable, mainly for two reasons. First, this reluctance might be a reaction to a considerably new tool that is quite different from the analysis currently in use (undiscounted payback period). It is worth mentioning that the participants have never before used ROA or NPV to select projects. Because ROA is based on the NPV concept and is not a complete departure from it, ROA would likely have been more accepted if participants had previously used NPV. Second, the survey was conducted within a manufacturing company that operates in a relatively stable industrial environment in which projects do not require highly costly and irreversible front-end commitments. We suspect that such conditions do not favor the emergence of ROA as a predominant analysis for portfolio management. Replicating the survey in a more dynamic environment, in which projects generate substantial front-end costs, should lead to different conclusions, especially if participants are already familiar with traditional financial analyses.

Beyond its direct applications in evaluating and selecting projects, ROA is leading to a better understanding of a firm's environment and its portfolio management context. An ROA mindset may even help to understand differences between companies and explain their distinct capabilities for seizing new emerging business opportunities, developing new products and bringing them to market in a timely manner, and conducting successful projects in dynamic environments (Trigeorgis and Reuer, 2017).

Given the limited number of participants and that the study is performed in a specific industry, these results should be considered with caution. For instance, we suspected that some participants might consider that their firm environment is relatively stable and that their projects revenues are fairly predictable. Consequently, they may have found that the proposed analysis was too sophisticated for their basic needs. Further research should focus on more diversified industries, preferably with a higher dynamic environment and more substantial investment costs.

	Project I	Project II
Maturity date	Now	3 years later
Investment cost	$100	$300
Present value	$110	$200 $
Volatility (σ)	0	30 %
Traditional NPV	$10	- $60
NPV including flexibility value	$10	$23

Table 2: Value calculation of Project II as a growth option.

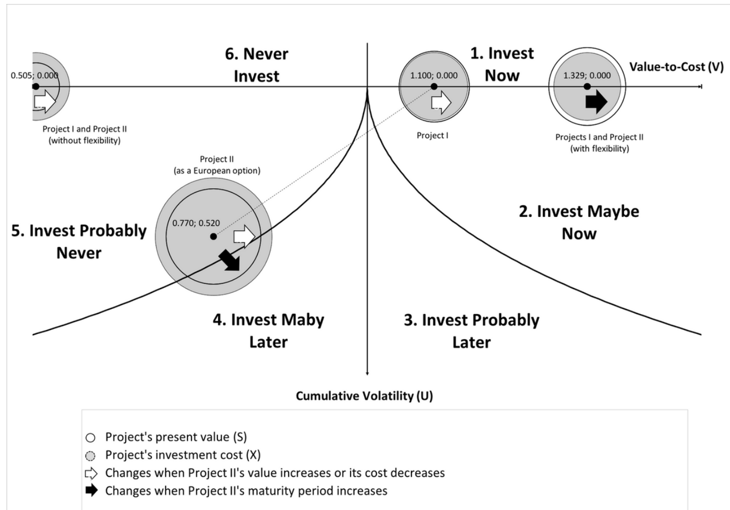

Figure 1: Representation of a growth option in the Project Garden.

	SRE	NPV	ROA	Means diff. sign
Accessibility Cronbach's alpha 0.697	3.79 (0.62) 4.00	3.58 (0.68) 3.63	3.23 (0.77) 3.17	0.000**
Relevance	4.20 (0.61) 4.33	4.27 (0.64) 4.33	4.07 (0.74) 4.17	n.s.
Completeness Cronbach's alpha 0.753	2.98 (0.44) 3.00	3.30 (0.51) 3.38	4.05 (0.52) 4.00	0.000****
Existence	3.31 (0.60) 3.00	3.50 (0.73) 3.00	3.69 (0.79) 3.50	0.037***
Consistency	N/A	3.59 (0.71) 4.00	3.59 (0.80) 4.00	n.s.
Level of Detail	3.81 (0.81) 4.00	3.86 (0.83) 4.00	3.91 (0.95) 4.00	n.s.
Project Portfolio Quality Cronbach's alpha 0.876	2.81 (0.76) 3.00	2.98 (0.66) 3.00	4.40 (0.52) 4.50	0.000****

Table 3: Descriptive statistics (mean, standard deviation and median) and significance of means test (Friedman non-parametric test – paired ANOVA test)1

1 Significant levels can be interpreted as follows:
n.s. = p > 0.10; * = p < 0.10; ** = p < 0.05; *** = p < 0.01; **** = p < 0.001.

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"An ROA mindset may even help to understand differences between companies and explain their distinct capabilities for seizing new emerging business opportunities, developing new products and bringing them to market in a timely manner, and conducting successful projects in dynamic environments."

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APPENDICES

		U															
	%	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	0.50	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.9	1.7	2.6	3.8	5.1	6.5	8.1	9.8	11.5
	0.55	0.0	0.0	0.0	0.0	0.1	0.3	0.8	1.6	2.6	3.7	5.1	6.6	8.2	9.9	11.7	13.6
	0.60	0.0	0.0	0.0	0.0	0.2	0.7	1.4	2.4	3.7	5.1	6.6	8.3	10.0	11.9	13.7	15.7
	0.65	0.0	0.0	0.0	0.1	0.5	1.2	2.3	3.5	5.0	6.6	8.3	10.1	11.9	13.8	15.8	17.7
	0.70	0.0	0.0	0.1	0.4	1.0	2.0	3.3	4.8	6.5	8.2	10.0	11.9	13.8	15.8	17.8	19.8
	0.75	0.0	0.0	0.2	0.8	1.8	3.1	4.6	6.3	8.1	10.0	11.9	13.8	15.8	17.8	19.8	21.8
	0.80	0.0	0.0	0.5	1.5	2.8	4.4	6.2	8.0	9.9	11.8	13.8	15.8	17.8	19.8	21.8	23.7
	0.85	0.0	0.2	1.2	2.5	4.2	6.0	7.9	9.8	11.8	13.8	15.8	17.7	19.7	21.7	23.7	25.7
	0.90	0.0	0.8	2.2	4.0	5.9	7.8	9.8	11.7	13.7	15.7	17.7	19.7	21.7	23.6	25.6	27.5
	0.95	0.4	2.0	3.9	5.8	7.8	9.8	11.8	13.8	15.8	17.7	19.7	21.7	23.6	25.5	27.4	29.3
	1.00	2.0	4.0	6.0	8.0	9.9	11.9	13.9	15.9	17.8	19.7	21.7	23.6	25.5	27.4	29.2	31.1
	1.05	5.2	6.7	8.5	10.4	12.3	14.2	16.1	18.0	19.9	21.7	23.6	25.5	27.3	29.2	31.0	32.8
	1.10	9.1	10.0	11.4	13.0	14.7	16.5	18.3	20.1	21.9	23.7	25.5	27.3	29.1	30.9	32.7	34.4
	1.15	13.0	13.4	14.4	15.7	17.2	18.8	20.5	22.2	23.9	25.7	27.4	29.1	30.9	32.6	34.3	36.0
	1.20	16.7	16.8	17.4	18.5	19.8	21.2	22.7	24.3	25.9	27.6	29.2	30.9	32.6	34.2	35.9	37.5
V	1.25	20.0	20.0	20.4	21.2	22.3	23.5	24.9	26.4	27.9	29.5	31.0	32.6	34.2	35.8	37.4	39.0
	1.30	23.1	23.1	23.3	23.9	24.7	25.8	27.1	28.4	29.8	31.3	32.8	34.3	35.8	37.3	38.9	40.4
	1.35	25.9	25.9	26.0	26.4	27.1	28.1	29.2	30.4	31.7	33.1	34.5	35.9	37.4	38.8	40.3	41.8
	1.40	28.6	28.6	28.6	28.9	29.4	30.2	31.2	32.3	33.5	34.8	36.1	37.5	38.9	40.3	41.7	43.1
	1.45	31.0	31.0	31.1	31.2	31.7	32.3	33.2	34.2	35.3	36.4	37.7	39.0	40.3	41.6	43.0	44.4
	1.50	33.3	33.3	33.3	33.5	33.8	34.3	35.1	36.0	37.0	38.1	39.2	40.4	41.7	43.0	44.3	45.6
	1.55	35.5	35.5	35.5	35.6	35.8	36.2	36.9	37.7	38.6	39.6	40.7	41.9	43.0	44.3	45.5	46.8
	1.60	37.5	37.5	37.5	37.5	37.7	38.1	38.6	39.3	40.2	41.1	42.1	43.2	44.4	45.5	46.7	47.9
	1.65	39.4	39.4	39.4	39.4	39.6	39.9	40.3	40.9	41.7	42.6	43.5	44.5	45.6	46.7	47.9	49.0
	1.70	41.2	41.2	41.2	41.2	41.3	41.5	41.9	42.5	43.2	44.0	44.8	45.8	46.8	47.9	49.0	50.1
	1.75	42.9	42.9	42.9	42.9	42.9	43.1	43.5	44.0	44.6	45.3	46.1	47.0	48.0	49.0	50.0	51.1
	1.80	44.4	44.4	44.4	44.5	44.5	44.7	44.9	45.4	45.9	46.6	47.4	48.2	49.1	50.1	51.1	52.1
	1.85	45.9	45.9	45.9	46.0	46.0	46.1	46.3	46.7	47.2	47.8	48.6	49.3	50.2	51.1	52.1	53.1
	1.90	47.4	47.4	47.4	47.4	47.4	47.5	47.7	48.0	48.5	49.0	49.7	50.4	51.3	52.1	53.0	54.0
	1.95	48.7	48.7	48.7	48.7	48.7	48.8	49.0	49.3	49.7	50.2	50.8	51.5	52.3	53.1	54.0	54.9
	2.00	50.0	50.0	50.0	50.0	50.0	50.1	50.2	50.5	50.8	51.3	51.9	52.5	53.3	54.0	54.9	55.8

Table 1: Relative (European) option value as a function of value-to-cost and cumulative uncertainty value

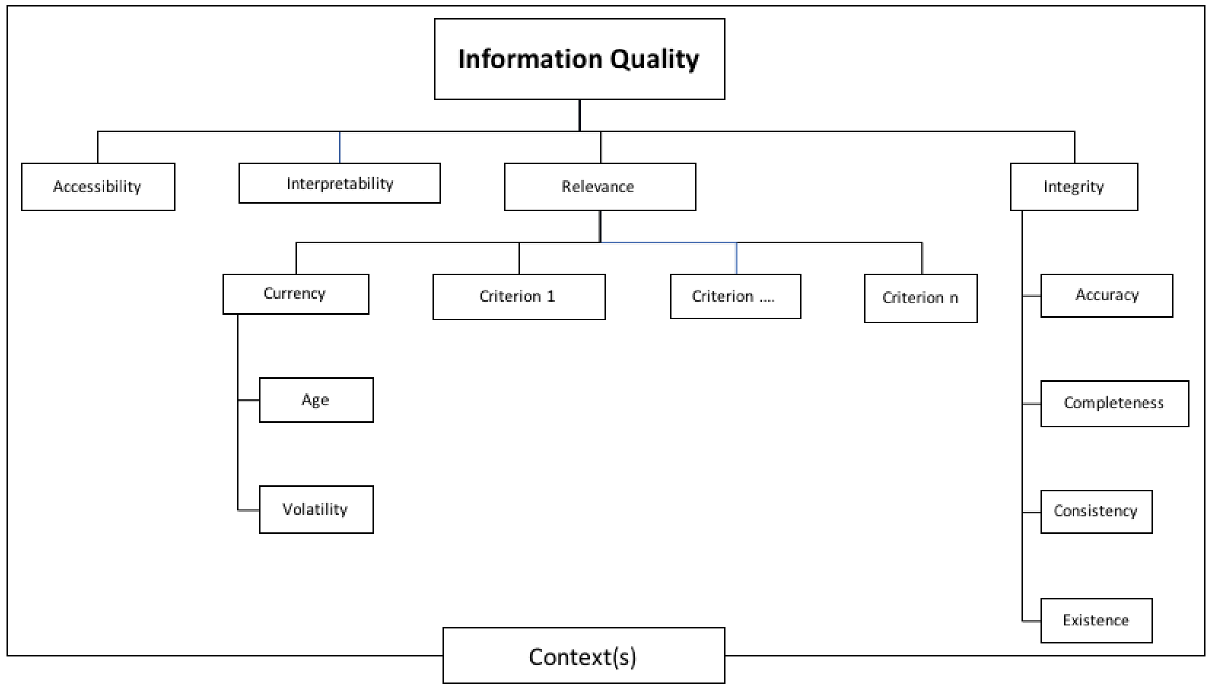

Figure 2: Attributes of Information Quality according to Bovee (2004:99).

Variable	Items
Section 1 - To what extent are the following statements important?	
Information Quality Importance Alpha = 0.898	Financial information about the new product is of high quality. Financial information about the new product is up to date. Financial information about the new product is accurate. Financial information about the new product is complete. Real information about the new product is available. Detailed information about the new product is adequate.
Financial Information Quality	Financial information about the new product is of high quality.
Financial Information Understandability	Financial information about the new product is easy to understand.
Section 2 - To what extent do you agree with the following statements about each analysis?	
Accessibility Alpha = 0.697	Information resulting from the analysis seems: easy to estimate, and to retrieve quickly at any time; easy to obtain; to provide realistic assumptions; to require specialized internal resources
Relevance Alpha = 0.762	Information resulting from the analysis seems: relevant; related to your firm's needs; to suit your firm's purposes
Project Portfolio Quality Alpha = 0.774	Information resulting from the analysis seems: to help build a project portfolio; create a well-balanced portfolio (long versus short term); create a well-balanced portfolio (low and high risks); establish priorities in the project portfolio; to maximize the value of the portfolio
Completeness (Integrity) Alpha = 0.753	Information resulting from the analysis seems: complete enough to make a decision; to reflect reality; to reflect all impacts; to provide a long-term competitive advantage through better decision-making; to provide a management tool that helps shape the strategic vision; to result in managerial flexibility; to provide a way of thinking about uncertainty and its effect on evaluation over time; to reflect the level of uncertainty; to facilitate flexibility in building strategies; to help establish risks, manage risks, evaluate financials, and non-financial information.
Consistency (Integrity)	Information resulting from the analysis is consistent compared with actual numbers.
Existence (Integrity)	Information resulting from the analysis seems to be reported without duplicates.
Level of Detail	Information resulting from the analysis seems to show the right level of detail.
Project Portfolio Fit	Information resulting from the analysis seems to have a project portfolio that reflects the strategy of the organization.
Present-day Relevance	Information resulting from the analysis seems to change at a manageable pace to stay current.
Error-free	Information resulting from the analysis seems error-free.

Table 4: Survey questions.